

VARIABLE INPUT CONSTANT OUTPUT 3-PHASE AC-DC CONVERTER

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**This thesis is submitted as partial fulfillment of the
requirements for the award of the
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Date : 29 NOVEMBER 2010

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ABSTRACT

Generator which powered by motorcycle engine will produce variable ac voltage because the engine running with difference RPM . If uncontrolled ac-dc converter is used, the output will be unhealthy variable DC voltage and not suitable for charging the battery. This project will use controlled ac-dc converter which will produce considerably constant output dc voltage at variable ac input. The converter uses controllable power switches to produce dc voltage output at 13-15 volt which is then can be use to charge the battery. The benefit of this project is it will be able to control the input from the three- phase generators vehicles specially motorcycle without any problem.

ABSTRAK

Penghasil kuasa yang menghasilkan kuasa dari enjin motosikal akan menghasilkan pelbagai arus ulang alik kerana enjin beroperasi dengan revolusi setiap minit (RPM) yang pelbagai. Jika penukar arus ulang alik kepada arus terus yang tidak dikawal digunakan, keluaran akan menghasilkan voltage arus terus yang tidak sesuai untuk digunakan sebagai pengecas bateri. Projek ini akan menggunakan penukar arus ulang alik kepada arus terus yang dikawal dimana akan menghasilkan arus terus yang tetap pada pelbagai masukan arus ulang alik. Penukar arus ini menggunakan suis kuasa untuk menghasilkan keluaran diantara 13 hingga 15 volt dimana ia akan digunakan untuk mengecas batteri. Faedah projek ini ialah ia akan mampu mengawal arus masukan daripada 3 fasa penghasil kuasa contohnya motosikal tanpa sebarang masalah.

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LIST OF ABBREVIATIONS

AC	-	Alternate Current
DC	-	Direct Current
SCR	-	Silicon Control Rectifier
PIC	-	Programmable Interface Controller
GTO	-	Gate Turn-Off Thyristor
VCD	-	Variable speed drive
THDI	-	Total Harmonic Distortion Current
MOSFET	-	Metal–Oxide–Semiconductor Field-Effect Transistor
HPF	-	High Power Factor
PWM	-	Pulse-Width Modulation
IC	-	Integrated Circuit

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CHAPTER 1

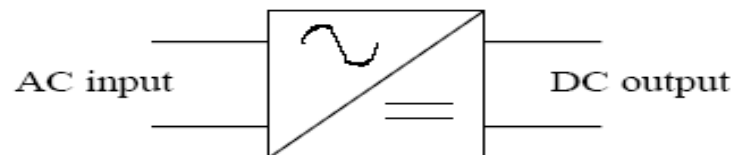
INTRODUCTION

1.1 Overview

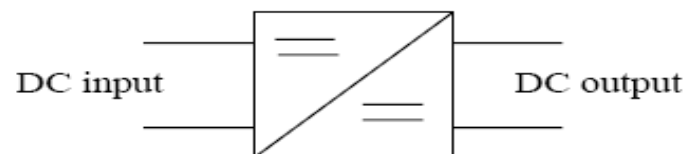
The modern era of power electronics began in 1958 ,when the General Electric Company introduced a commercial thyristor ,two years after it was invented by Bell Telephone Laboratory. Soon all industrial applications that were based on mercury arc rectifiers and power magnetic amplifiers were replaced by silicon-controlled rectifiers(SCRs).In less than 20 years after commercial SCRs were introduced significant improvements in semiconductor fabrication technology and physical operation were made ,and many different types of power semiconductor devices appeared. The growth in power electronics was made possible with the microelectronic revolution of the 1970s and 1980s, in which the low power IC control chips provided the brain and the intelligence to control the high – power semiconductor devices .Moreover the introduction of microprocessors made it possible to apply modern control theory to power electronics. In the last 20 years ,the growth in power electronics application has been remarkable because of this introduction of very fast and high-power switching devices, coupled with the utilization of state-of –the –art control algorithms. An electric power can be converted from one form to another form by using power electronics devices. The function of power electronics circuits by using semiconductor devices as switch is modifying or controlling a voltage. The goal of power electronics circuits are to convert electrical energy from one form to another, from source to load with highest efficiency, high availability and high reliability with the lowest cost, smallest size and weight.

There are four conversion circuits that are used in the majority of today's power electronics circuits. Firstly are ac-to-ac ,secondly is ac-to-dc ,thirdly is dc-to-ac and the last is dc-to-dc. In terms of functional description ,modern power electronics system perform one or more of the following conversion functions.

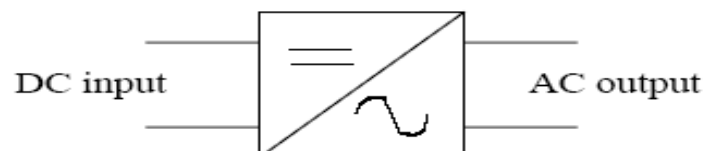
AC to DC : Rectifier



DC to DC : Chopper



DC to AC : Inverter



AC to AC : Cycloconverter

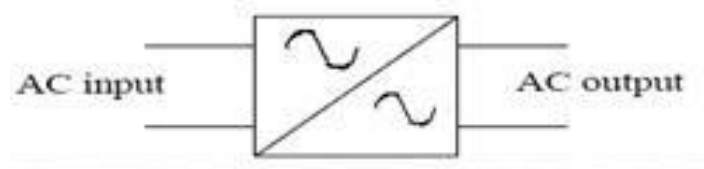


Figure 1.1: Four Types of Conversion

1.2 Background

Power electronic converters can be found wherever there is a need to modify a form of electrical energy (i.e. change its voltage, current or frequency). The power range of these converters is from some milliwatts (as in a mobile phone) to hundreds of megawatts (e.g. in a HVDC transmission system). With classical electronics, electrical currents and voltage are used to carry information, whereas with power electronics, they carry power. Thus, the main metric of power electronics becomes the efficiency.

The first very high power electronic devices were mercury arc valves. In modern systems the conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices, e.g. television sets, personal computers, battery chargers, etc. The power range is typically from tens of watts to several hundred watts. In industry the most common application is the variable speed drive (VSD) that is used to control an induction motor. The power range of VSDs start from a few hundred watts and end at tens of megawatts.

Power electronics refers to control and conversion of electrical power by power semiconductor devices wherein these devices operate as switches. Advent of silicon-controlled rectifiers, abbreviated as SCRs, led to the development of a new area of application called the power electronics. Prior to the introduction of SCRs, mercury-arc rectifiers were used for controlling electrical power, but such rectifier circuits were part of industrial electronics and the scope for applications of mercury-arc rectifiers was limited. Once the SCRs were available, the application area spread to many fields such as drives, power supplies, aviation electronics, high frequency inverters and power electronics originated.

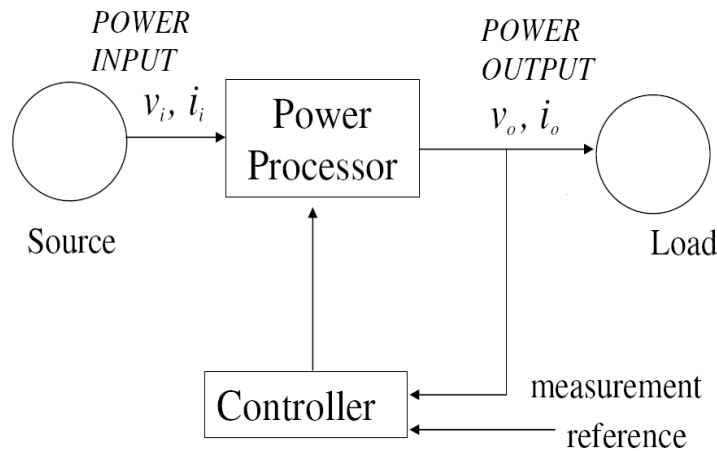


Figure 1.2: Power Processor & Controller

1.3 Objective

The first objective or the purpose of this project is to design a circuit to convert the variable ac input voltage to constant dc output voltage. The second objective is to develop hardware of the system where the output voltage will be able to charge 12V rechargeable lead acid battery.

1.4 Scope

This project concentrates on development circuit and hardware to get constant dc output at variable ac input that generated by 3-phase generator. This converter using 3-phase controlled rectifier that use SCR and PIC (Programmable Interface Controller) as main component.

After designing and build rectifier circuit, the control circuit should be able to control the voltage by adjusting the delay angle α . The delay angle will be adjusted by using programming of PIC.

The voltage output is about 13-15 volt. The output voltage then is able to charge the lead-acid battery.

1.5 Problem Statement

A rectifier is an electronic circuit that converts bidirectional voltage (AC voltage) to unidirectional voltage (DC voltage) by using power diodes or by controlling the firing angle of thyristor or controllable switches. Rectifier usually can be divided into two types that are uncontrolled rectifier and controlled rectifier. Each type can have either single phase or three-phase. A diode is the simplest electronics switch which it is uncontrolled that the on and off states can be determined by the power supply in the circuit itself. AC to DC converter is mostly used in industries and also in domestic equipment. Generator from car/motorcycle that running at different rpm will produce different AC output voltage, hence provide variable DC voltage if uncontrolled AC-DC converter is used. This variable DC voltage is not suitable to charge the battery of the vehicle.

Hence, to overcome this problem there is a way to control the output voltage of the rectifier. Basically, the three phase rectifier is designed using the thyristors or more specifically are called Silicon Control Rectifier (SCR) which connected in full-wave rectifier. A thyristor is four layers (pnpn) semiconductor devices that act as switches, rectifiers or voltage regulators. Thyristors are electronic switches used in power electronics circuits where control of switch turn-on is required. Thus, the output voltage can be set at any constant voltage value by controlling the delay angle of the SCR although generator produce at any voltage range.

1.6 Thesis Outline

There are all five chapters being structures in this thesis and every chapter will elaborate in detail about this project. For the first chapter, an overview about this project, variable input constant output 3 phase ac-dc converter is discussed including the objectives and scopes of the project as a guide to develop three phase controlled rectifier.

Chapter 2 will explain and discuss on the literature review of the three phase controlled rectifier. The literature review is taken from jurnal/proceeding with related to the project.

Chapter 3 discusses the methodologies of the three phase controlled rectifier that has been applied in completing this project. In this chapter, it consists of block diagram and flow chart which are explained about the process of implementation and how the three phase AC voltage converts to DC voltage then connected to the battery as a load. It is also discusses briefly how the output voltage can be varied.

Chapter 4 is discussing and displaying all the results obtained and the limitation of the project. All discussions are concentrated on the result and the overall performance of the three phase controlled rectifier.

Chapter 5 in overall will discuss on the conclusion and summary of the development of the three phase controlled rectifier project. In this chapter also discusses on the recommendation for this project development or modification.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter presents an overview of rectifier. A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC). Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components.

The rectifier also use for vehicle. There are some uses of rectifier in vehicle such as for electric vehicle, trolleybus systems, mechanical batteries and others. Hence, this project proposed for the control of output voltage for vehicle such as motorcycle to produce constant voltage from its alternator. There are many type of rectifier that can be use for the vehicle.

2.2 Synchronous Rectifier

The synchronous rectification is a technique for improving efficiency of power converters in power electronics. It consists of connecting a diode and a transistor (usually a power MOSFET) in parallel. When the diode is forward-biased, the transistor is turned on, to

reduce the voltage drop. When the diode is reverse-biased, the transistor is turned off, so no charge can flow through the circuit. This way, a rectifying characteristic is obtained, without the forward voltage drop associated with diodes in the on-state.

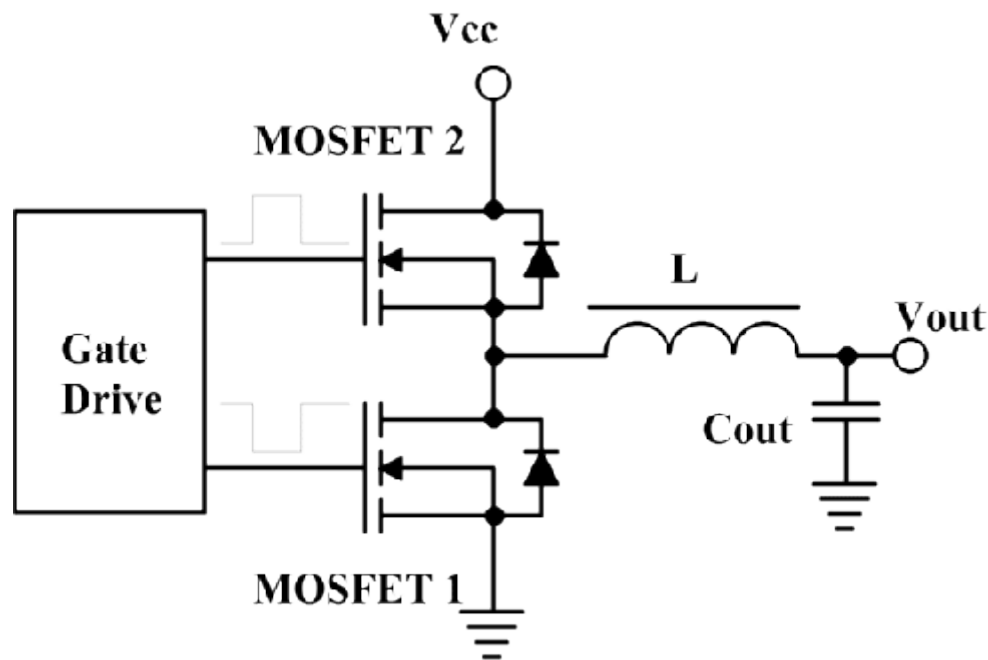


Figure 2.1: synchronous rectifier

Decreasing world oil and gas resources as well as environmental concerns have driven automotive industry to develop more efficient and cleaner vehicles to reduce fuel consumption and protect the environment. The hybrid vehicle technology offers a reasonable solution for the challenges of energy and environment. Power to the wheels can be provided solely by the battery pack through the electric motor, directly from the gasoline engine to the wheels, or from a combination of both the propulsion motor and the engine. Electric power flow from PV arrays is controlled using a boost converter so that PV arrays operate at the most efficient point. Various operating points can be obtained by varying the short-circuit level (which is proportional to the solar irradiation) and the temperature. The generated electric power is controlled through a synchronous rectifier to store energy within the battery pack of the vehicle [1].

Present passenger vehicles' standard electrical power supply is provided by a belt-driven claw-pole synchronous machine and a bridge-connected diode rectifier (Figure 2.2). An integrated regulator controls the vehicle-net voltage U , by varying the excitation current I .

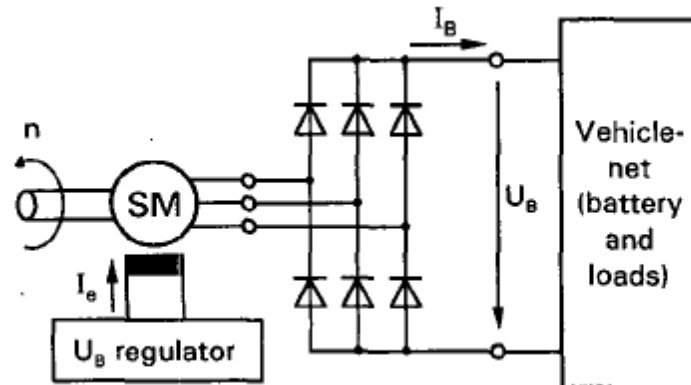


Figure 2.2: Simplified schematic of a vehicle's electrical power supply

The output current I , is driven into the vehicle-net by the induced alternator voltage, starting at the specific so-called “0-ampere-speed” and following a characteristic as shown in Figure 2.3 for a fully excited alternator. Besides this induced alternator voltage, I , is determined by the vehicle-net voltage U , and the electrical parameters of the circuit, such as stator reactance, stator resistance, line resistance and the forward voltage of the rectifier diodes [8].

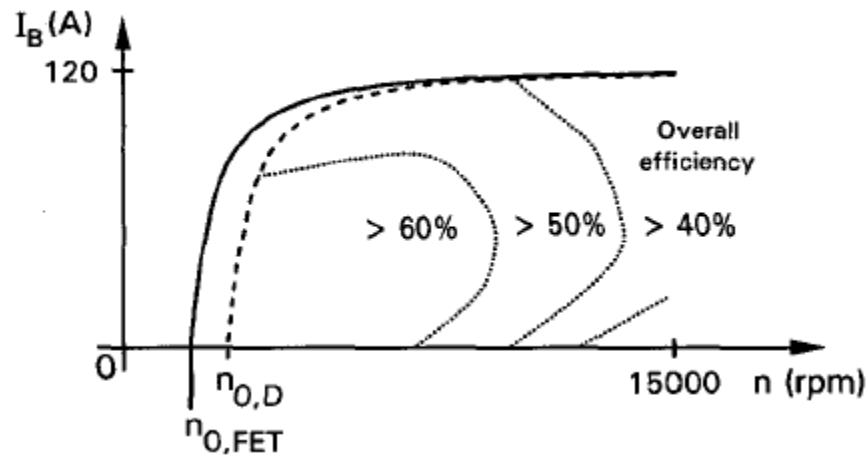


Figure 2.3: Example output characteristic of a passenger vehicle alternator (fully excited) equipped with a conventional rectifier and with a synchronous rectifier using MOSFETs.

2.3 Hybrid Rectifier

Single-phase hybrid rectifier structure with high power factor (PF) and low harmonic distortion of current (THDI), suitable for application in traction systems of electrical vehicles pulled by electrical motors (trolleybus), which are powered by urban distribution network. Front-end rectifier structure is capable of providing significant improvements in trolleybuses systems and in the urban distribution network costs, and efficiency. The Trolleybus System is a kind of vehicle that has been rapidly developed as a sophisticated, non-polluting, silent, fast, and popular public urban transport widely used in Europe since 1911 [7]. The proposed structure is composed by an ordinary single-phase diode rectifier with parallel connection of a switched converter. It is outlined that the switched converter is capable of composing the input line current waveform assuring high power factor (HPF) and low THDI, as well as ordinary front-end

converter. Concerning the development of power electronic converters for trolleybus system applications, one of the great challenges faced by researchers is to develop electronic traction control systems with reduced weight and size, once that these converters, usually connected to a DC distribution network, must be able to deal with high power levels, around 150kW.

This converter must also be able to supply the demanded high power assuring high power factor and low current harmonic distortion when in AC, due to many disadvantages of the presence of harmonic current components in the AC distribution network, maintaining the same performance when in DC. Therefore, the power electronic converters used in trolleybuses, when supplied by single-phase AC distribution networks require a front-end rectifier in order to provide an intermediate DC link for connection of DC or AC adjustable speed drivers.



(a)



(b)

Figure 2.4: Trolleybuses (a) in the city of São Paulo – Eletra (b) Projects in development in Europe

When operating in AC, those front-end converters represent a medium to high power single-phase non linear loads, and if concentrated only in one phase of the three-phase power system, it will cause unbalances and many disadvantages related to the presence of harmonic current components in the AC distribution network due to its operation characteristics. In this way, a Scott transformer is a kind of equipment widely used in order to convert the three-phase power supply into two single-phase power supplies, distributing the load between the primary windings of the transformer and, therefore, mitigating the unbalance problems.

However, the input line current waveform of conventional diode-rectifier circuits presents itself as a non-sinusoidal waveform, thus, the implementation of robustness and reliable front-end converters capable of operating in accordance with harmonic content restrictions imposed by international standards such as IEC 61000-3-4, becomes a mandatory issue [2].

The major advantage provided by hybrid rectifiers, three-phase or single-phase, is the association of the robustness, simplicity, and reliability of diode-rectifiers with the reduction of volume, weight, and size provided by high frequency switched converters. Thus, the rated power can be drastically increased without compromising the global structure efficiency. The main advantages achieved when hybrid rectifiers are used in order to provide intermediate DC link for power electronic converters connection are:

- Higher global efficiency once that the switched converter must be rated at a fraction of the nominal power.
- Reduced weight and size when compared to ordinary single-phase HPF front-end rectifiers.
- Flexibility in attention to IEC61000-3-4 limits, since the input line current waveform can assume different wave shapes, depending on the desired THDI.
- Simple, efficient, and low cost control technique.

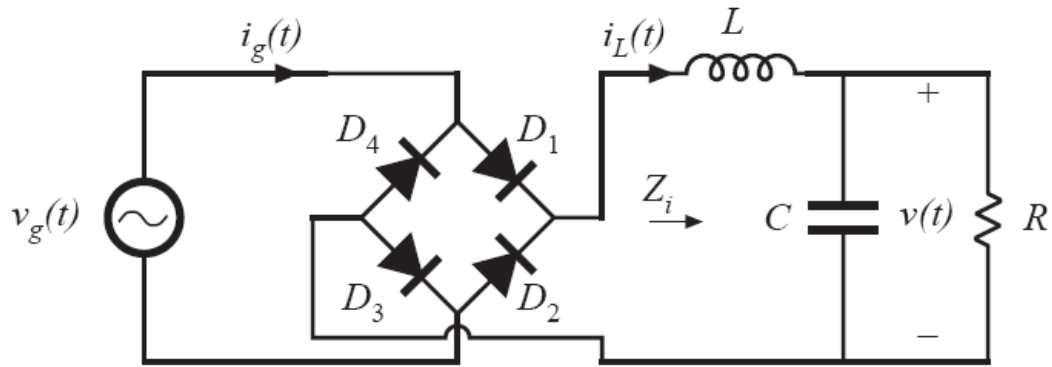


Figure 2.5: Single-phase diode-rectifier

The proposed single-phase front-end hybrid rectifier is composed by the combination of two rectifiers groups. the control strategy must focus on the imposition of a nearly sinusoidal AC input-line current, as well as on limiting the switched converter power contribution at 34% of the total output power, in order to avoid that the switched converter assumes the total output power. Otherwise, the output voltage becomes higher than the input and the diode-rectifier becomes inactive, which could take the switched converter to destruction.

2.4 PWM Rectifier

PWM rectifier is an AC to DC power converter, which is implemented using forced commutated power electronic semiconductor switches. Today, insulated gate bipolar transistors are typical switching devices. Different from diode bridge rectifiers, PWM rectifiers achieve bidirectional power flow. In frequency converters this property makes it possible to perform regenerative braking. PWM rectifiers are also used in distributed power generation applications, such as micro turbines, fuel cells and windmills.

The dc power supply in traction power conversion system is provided by uncontrolled diode and phase-controlled thyristor rectifier in feeding system of high-speed maglev vehicles, Shanghai.

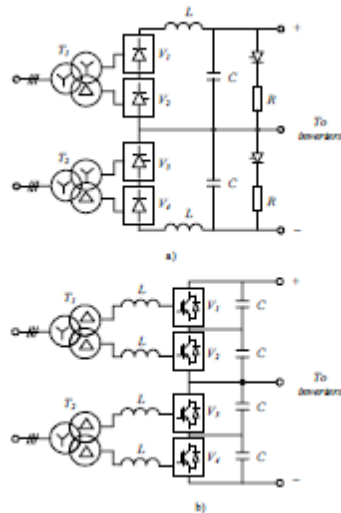


Figure 2.6: Configuration of the two rectifier systems

Due to the distinct advantages of PWM rectifier, substituting multi-module PWM rectifier for uncontrolled diode and phase-controlled thyristor rectifier can obtain a optimal system configuration. In multi-module PWM rectifier system, only small high-frequency harmonic filters are required. The braking energy can flow back to utility through PWM rectifier. At the same time, PWM rectifier has the ability to improve the dynamic performance of whole system with fast response.

The three-phase PWM rectifier offers distinct advantages compared to conventional uncontrolled diode or phase-controlled thyristor rectifier. The advantages include nearly sinusoidal input currents, controllable input power factor, high quality dc output voltage, and bidirectional power flow. With proper control approach, the multi-module PWM rectifier can achieve harmonic reduction while maintaining low switching frequency. PWM rectifier has the ability to improve the dynamic performance of whole system with fast response [3].